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(54) Uninterruptible power supply for an electronic computer

(57) In the event of loss of normal AC mains supply, the computer is supplied from a battery F via an inverter E the frequency of operation of which is varied, preferably over the range 45 to 85 Hz, in dependence on the load current sensed by a monitor A so that the power output of the inverter E meets the demand. Software within the computer checks on the energy level remaining in the battery F and when this level reaches a predetermined value the software inhibits further normal computer operation and executes computer shut-down by storing the contents of a volatile memory K on non volatile media J followed by switching off the computer and VPS. The computer software performs a check when the computer is first switched on to determine the type of battery in use and thereafter the state of the battery is compared with known discharge characteristics of that battery to determine the remaining battery energy level. The amplitude of spikes and down kicks, (Figs 4B,C), in the instantaneous battery voltage occurring at the inverter switching frequency, may be compared with known values to determine remaining energy.

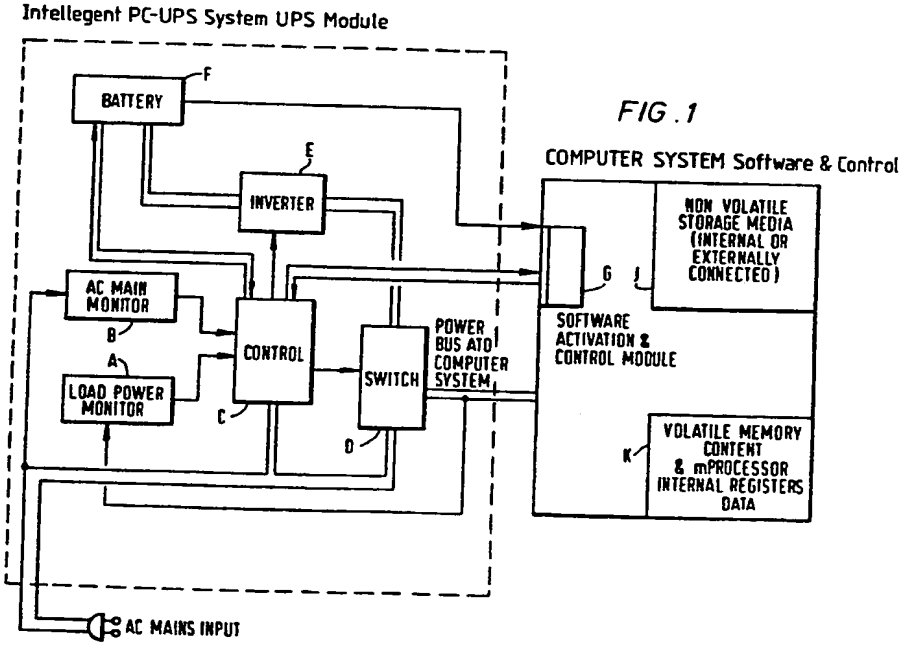

FIG. 1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1990.

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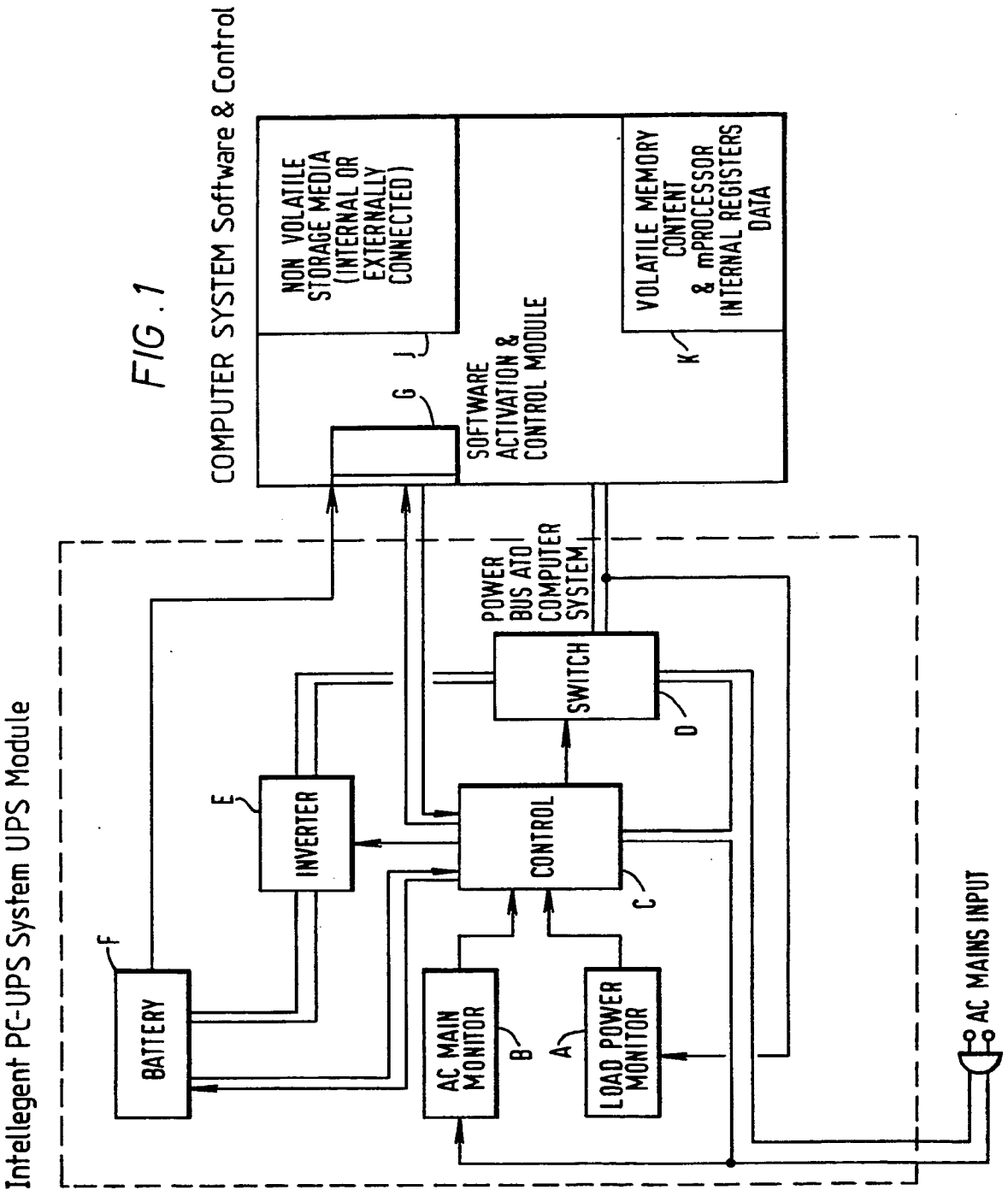
FIG. 1



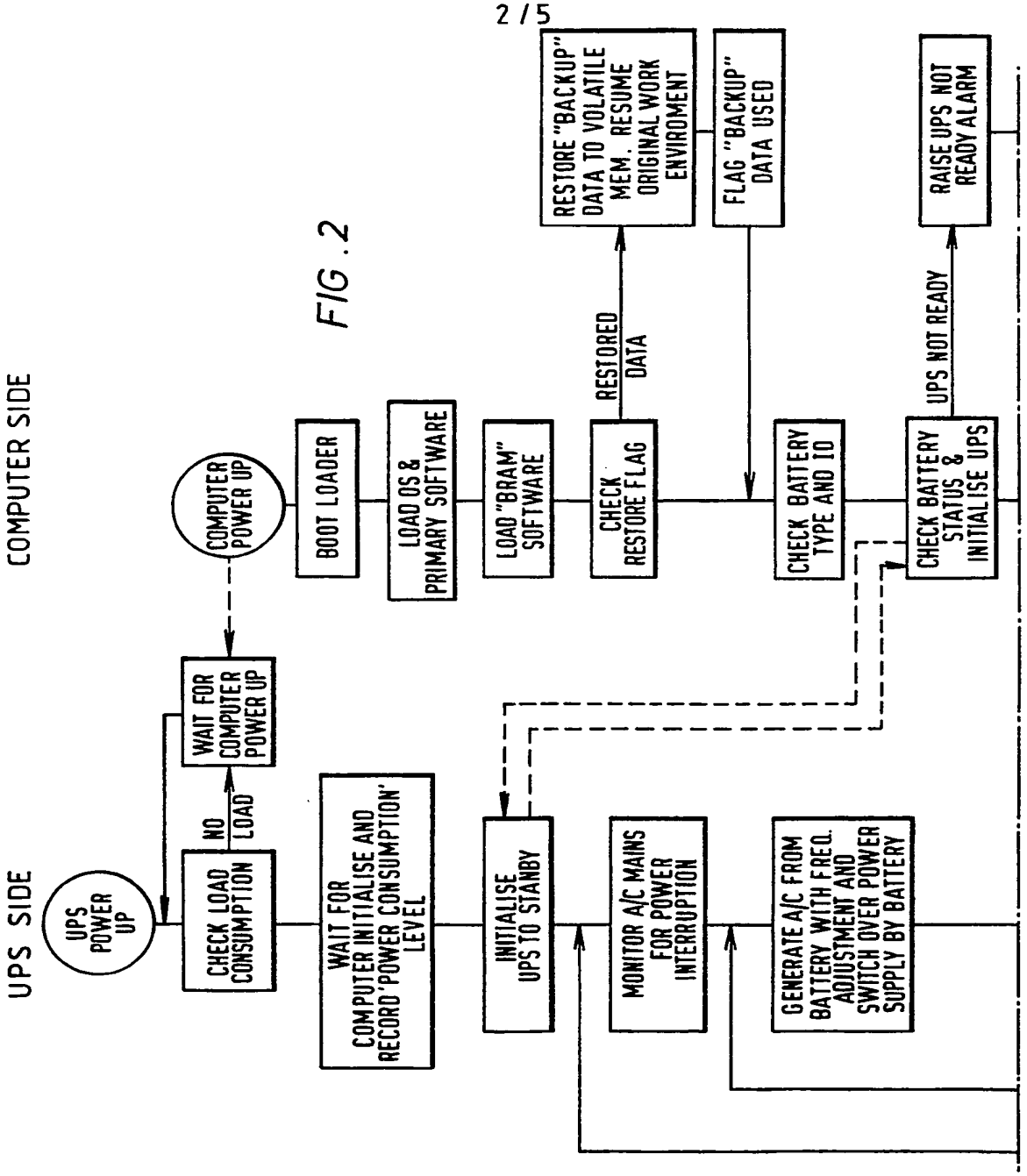

UPS SIDE
COMPUTER SIDE
UPS POWER UP
CHECK LOAD CONSUMPTION
NO LOAD
WAIT FOR COMPUTER POWER UP
WAIT FOR COMPUTER INITIALISE AND RECORD 'POWER CONSUMPTION' LEVEL
INITIALISE UPS TO STANBY
MONITOR A/C MAINS FOR POWER INTERRUPTION
GENERATE A/C FROM BATTERY WITH FREQ. ADJUSTMENT AND SWITCH OVER POWER SUPPLY BY BATTERY
COMPUTER POWER UP
BOOT LOADER
LOAD OS & PRIMARY SOFTWARE
LOAD "BRAM" SOFTWARE
CHECK RESTORE FLAG
RESTORED DATA
RESTORE "BACKUP" DATA TO VOLATILE MEM. RESUME ORIGINAL WORK ENVIROMENT
FLAG "BACKUP" DATA USED
CHECK BATTERY TYPE AND IO
CHECK BATTERY STATUS & INITIALISE UPS
UPS NOT READY
RAISE UPS NOT READY ALARM

FIG.2

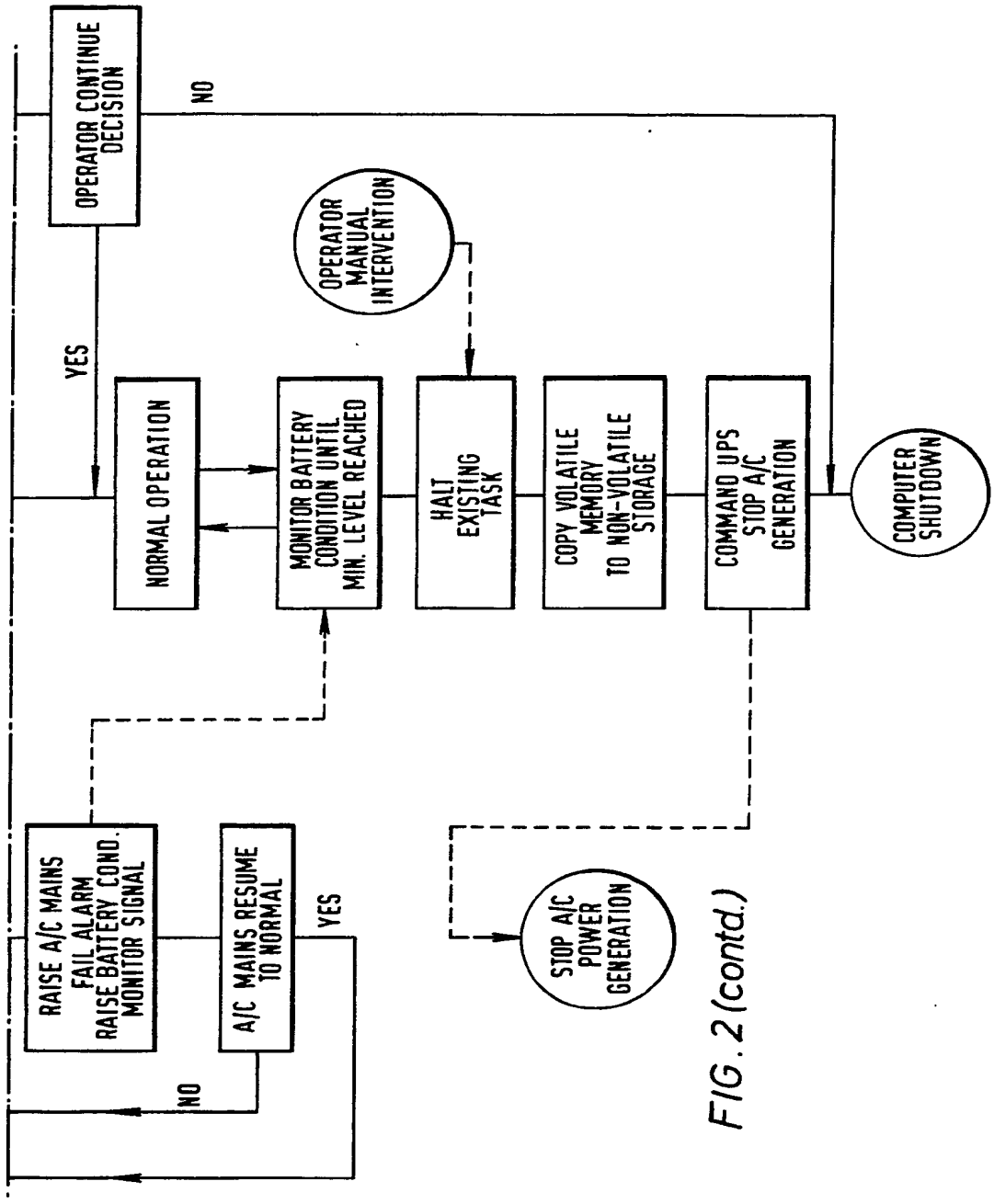


FIG. 2 (contd.)

FIG. 3

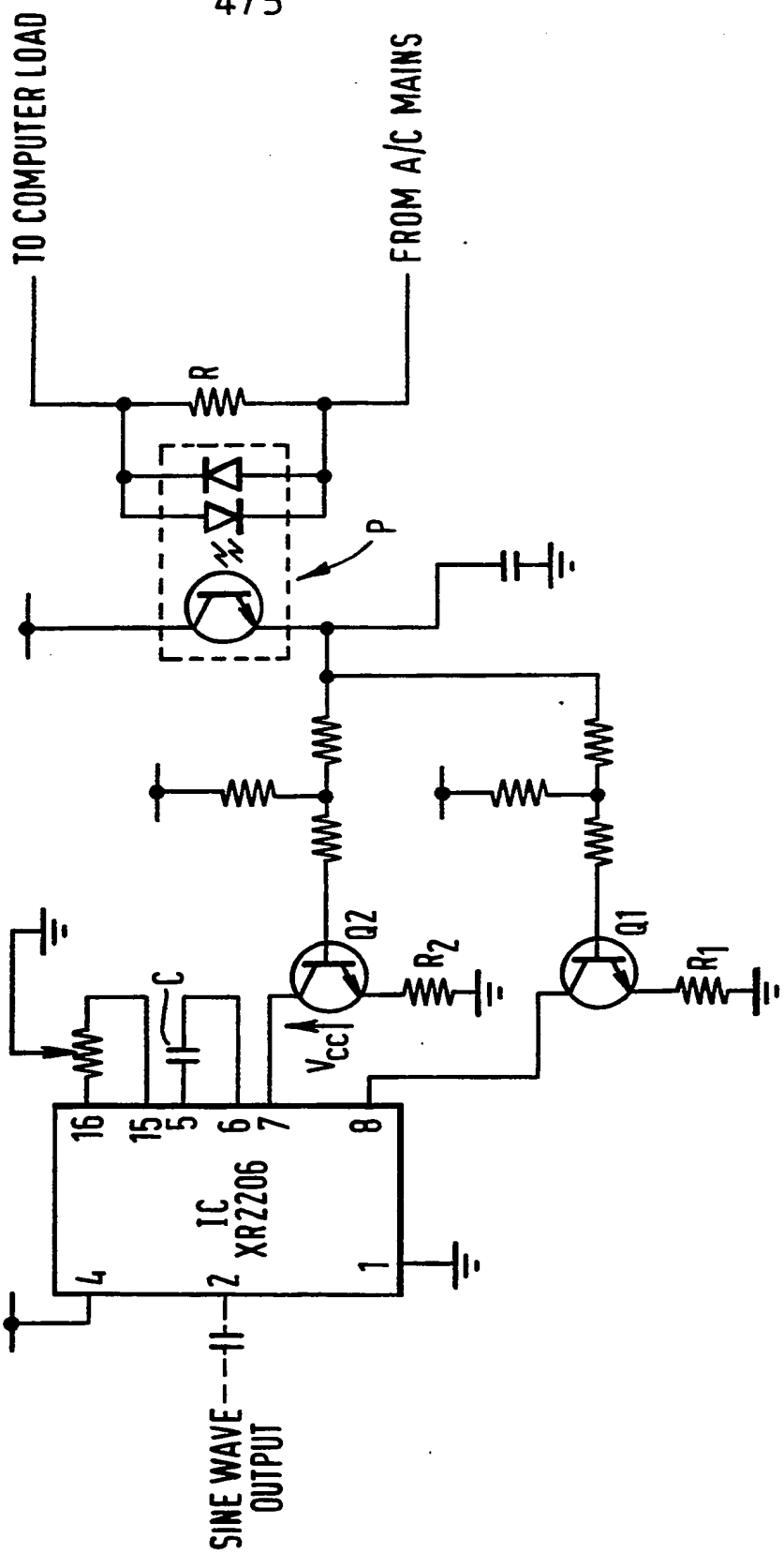
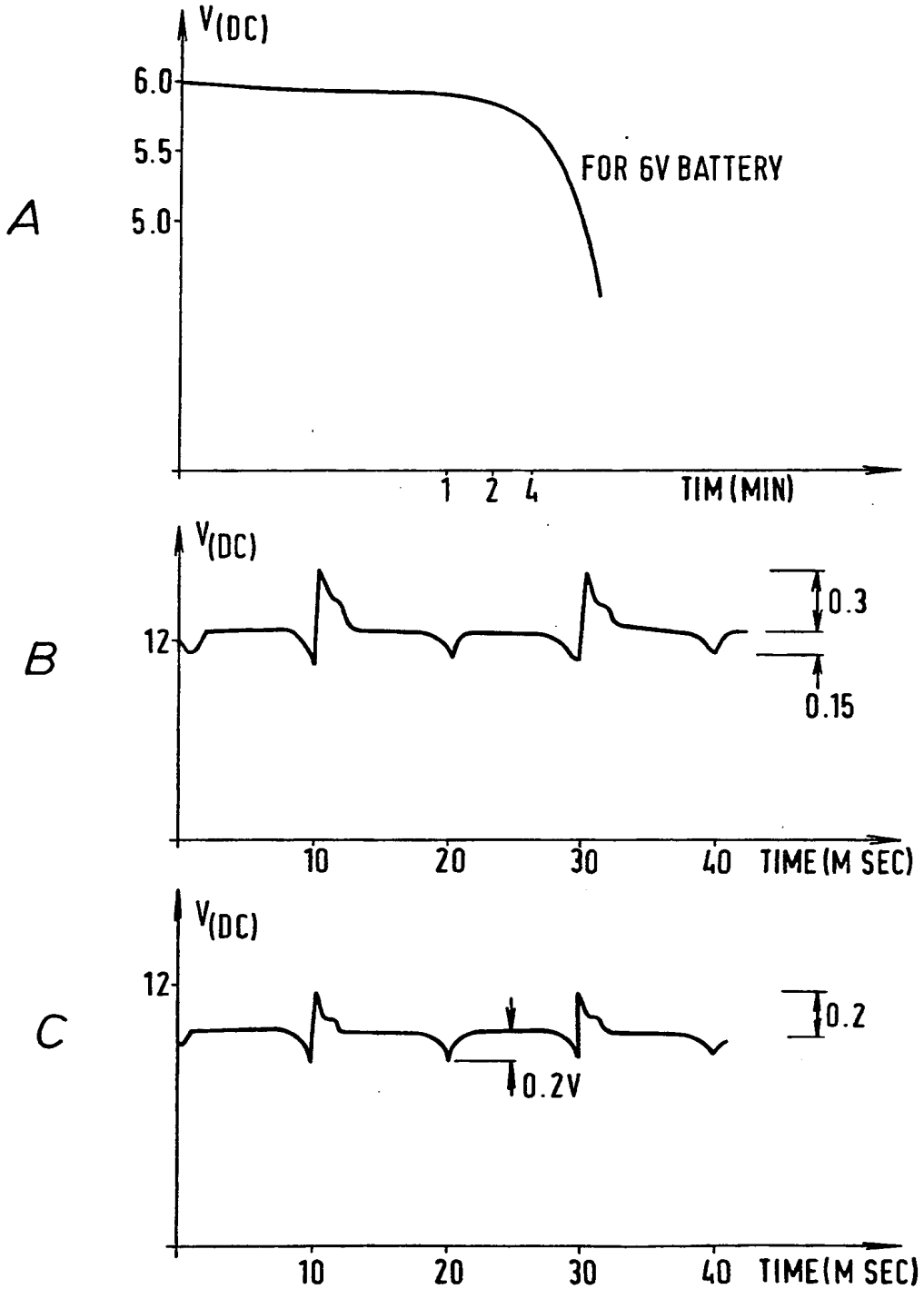


FIG. 4



AN UNINTERRUPTED POWER SUPPLY

This invention relates to an uninterrupted power supply (UPS) for an electronic computer.

Generally speaking computers are powered from the AC mains supply and have their own power supply unit which converts the AC mains input to one or more stabilized DC outputs. Continuity of output DC is critical, particularly the DC supply, usually at 5V, to power the electronic circuits since any loss of supply or serious discontinuity in the 5V output will result in a loss of the data stored in the volatile memory circuits of the computer.

To avoid this it has been proposed to provide some form of battery backup to the DC outputs so as to provide continuity of operation in the event of failure of the AC mains supply and such arrangements have become known as a UPS.

Generally a UPS comprises the following:

i. a number of DC batteries to store up sufficient electrical energy for AC power generation;

ii. an inverter to generate replacement AC power from the DC battery;

iii. a detection control unit to detect for mains AC power failure and the control of AC source

transfer; and

iv. a charger to charge the electrical batteries when the battery energy level is low.

With the use of a conventional UPS, the problem of data corruption is still not solved however.

In the UPS structure, one or more step-up transformers are usually employed for converting low voltage battery energy to high voltage AC energy. To enable the transformer to transfer sufficient energy, the windings should be large enough to carry sufficient electrical current. Also the iron core should be large enough to maintain sufficient magnetic flux for energy transfer. It is for the above reasons that a conventional UPS is bulky.

During a power failure, a conventional UPS only provides the operator with audio and video alarm. When the battery energy has drained off, a conventional UPS will stop trying to generate AC power to the computer irrespective of whether the computer is in operation or not, ie data loss is still unavoidable.

A conventional UPS is built as an independent unit and there is no communication between the UPS and the computer.

Since all UPS have a fixed capacity of energy, if power is interrupted while the computer is performing time-consuming calculations, forcing the computer to

shutdown might abort the program at middle of a calculation. In such cases all pre-computed data may not be recovered.

Since the UPS backup time is fixed and usually limited to say 10 to 30 minutes it is extremely risky for the operator to leave the computer running unattended.

Since battery energy stored varies with battery age and charging time, it is impossible by ordinary means to measure the energy remaining in the battery. Hence during power interruption, the operator will be unable to judge the time at which the computer should be shutdown before battery energy has drained off.

It is therefore an object of this invention to provide an improved UPS in which one or more of these problems are mitigated and/or avoided.

According to the invention in one aspect there is provided an uninterrupted power supply (UPS) for an electronic computer, comprising battery storage means, an inverter for converting energy from the battery means to an AC output for supply to the normal AC input of the power supply of the computer, detector means for detecting an interruption in normal AC mains supply and switching to supply from the inverter, means for monitoring the load current drawn by the computer and adjusting the frequency of operation of the inverter to vary the frequency and so its output to meet the demand, and software means within

the computer receiving a signal from the detector means upon interruption of AC mains supply for checking on the level of energy remaining in the battery storage means and, when this level reaches a minimum chosen level, inhibiting further normal operation of the computer and executing a shut-down of the computer by storing the contents of the volatile memory of the computer on permanent media following by switching off the computer and the UPS.

With such a system the monitoring means can ensure that the energy supplied from the batteries is not wasted. Thus a larger supply can be provided to meet peak demands but equally a lower supply can be drawn if the output demand reduces. In this way the storage battery power can be used to good advantage. Also the size of the transformer in the inverter can be kept small since one does not need to use its stored magnetic flux to smooth the output power supply and so cover peak demands. We have also appreciated that most conventional power supplies for computers will accept a wide range of input AC frequencies and so it is possible for the inverter operating frequency to be varied without serious consequences.

The software means continuously check on the power remaining in the battery power and only execute the saving and the shut-down when the remaining power reaches a point where there is only sufficient left for an orderly shut-down. Thus, whilst the battery means can satisfactorily power the computer, normal computer

operation can continue. Once it is determined that the power remaining is only sufficient for the shut-down operation, then the software means take control of the computer operations, and store all the contents in the volatile memory and the contents of the computer registers in a pre-reserved place on permanent media such as a hard disc or a floppy disc. Thereafter the computer and the UPS are shut down. In this way one can ensure that no data is lost and the computer can, upon restarting, load the data from the permanent media as a first step and so the computer, when it restarts, can be made ready to start again immediately at the point where it was shut down.

An advantage of using software means to monitor the remaining battery power is that the software means can determine with some accuracy the remaining power and so can allow the UPS to continue to operate until all the usable power is consumed. Thus in many UPS a shut-down will be performed after a certain length of time, but this pre-supposes that the battery means are fully charged, takes no account of the actual amount of power which has been drawn, and no account of the age or condition of the battery means. Thus, in the arrangement according to the invention, one can instead check the actual remaining battery power.

According to one embodiment of the invention the software means perform a check when the computer is first switched on to determine the type of battery means, and then compares the state of the battery when the UPS is actuated with the known discharge characteristics of the battery and so continuously determines the remaining battery power by comparing the instantaneous battery output with the known characteristics.

In particular the output voltage of a battery against time under steady discharge tends not to vary initially when the battery is fully charged. Suddenly, however, towards the end of its capacity the output voltage will drop rapidly. It is therefore almost impossible to predict the point at which this output voltage drop will occur simply by monitoring the actual output voltage.

According to one advantageous embodiment of the invention, however, we have found that the instantaneous output voltage when under the varying load drawn by the inverter has a characteristic, for each individual type of battery, which does vary with the discharge time. Thus the instantaneous voltage will exhibit characteristic spikes and down kicks at the frequency of operation of the inverter and, unlike the output voltage under steady discharge, the values of these peaks and down drops varies significantly with the extent of discharge of the battery

and so one can monitor these and obtain an accurate figure for the instantaneous remaining battery power by comparing these values with the known values for a particular battery.

The invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a block diagram of a UPS according to the invention linked to a computer;

Figure 2 is a flow chart illustrating the operation of the UPS and its associated computer;

Figure 3 is a simplified circuit diagram of the inverter used in the UPS; and

Figure 4 is a diagram showing various characteristics of a particular battery.

When the UPS module is powered up, the load/power monitor A will start to detect the load current which is also a detection that the computer is turned ON. When the computer is not turned ON, there should be no load current. The monitor A will keep track of the powering up of the computer.

When the computer powers up, the output current will activate the monitor A and will wait for the initialization command from the computer.

After receiving the initialization command from the computer, the UPS control C will initialize all UPS elements and the monitor A will record the power consumption level for future reference. This level is an actual measurement of the power required by the computer during normal operation.

AC mains monitor B then comes into action, the power line voltage will be monitored for voltage loss, voltage drop or any kind of voltage interruption. This process will be continued until a voltage interruption happens or the UPS shuts down.

Upon mains voltage interruption, the monitor B will send a signal to a UPS control C which will then control an inverter E to start generating AC power from the battery F.

At the same time, monitor C will control a UPS switch D to switch over the source from AC mains to the inverter E.

The load monitor A will keep track of the load power and compare it with the previously recorded power consumption level for frequency adjustment. The control C will also at the same time raise an alarm/warning signal to the computer which will in turn activate battery condition monitoring software to be described.

Figure 3 shows in more detail the inverter E and its frequency control.

A resistor R, eg of 20W handling load is provided in series with the load computer load as a way to measure the AC load current. Thus the voltage drop across the resistor R will have a linear relationship with the load current.

By choosing the correct value for a particular load range, the voltage drop across the resistor R at minimum load should be just about to turn on the photo-diode inside a photo-coupler P.

This photo-coupler P will in turn supply current to the bases of two transistors Q1 and Q2.

The chip IC XR2208 is set up as a sine wave generator. The output is at pin 2 where it will provide a 50 Hz sine wave switching frequency to the inverter.

The degree to which transistors Q1 and Q2 are turned on will affect the charging and discharge timing of the IC internal circuit having RC components consisting of a capacitor C, and resistors R1 and R2 associated with respective transistors Q1 and Q2.

When the load current is high, the voltage drop across resistor R increases. Therefore the time for which the photo-diode is "on" increases. The photo-coupler transistor will drive more current to transistors Q1 and Q2 resulting to less voltage drop V across the transistors Q1 and Q2 which speeds up the charge and discharge timing.

In this way, the output frequency at IC pin 2 will increase and hence this will increase the inverter frequency.

Conversely when load current is small, the photo-diode will be less active, and so transistors Q1 and Q2 will not be turned on as hard as previously described, resulting to a drop in the generated frequency.

This circuit will therefore operate automatically to increased and decrease the frequency of the inverter and hence increase and decrease its output power according to the load demand from the computer.

The circuit can control the inverter frequency over the range of 40Hz to 200 Hz. However the frequency range should preferably be limited to 45Hz to 85Hz to meet computer's input specification.

The UPS will continue to generate AC power until:

i. the AC mains resumes to normal; in this case, the UPS will resume operation with voltage mains monitoring by monitor B,

ii. a shutdown command is issued by the computer; in this case, the UPS will shutdown the inverter E and the complete hardware will be reset.

Before powering up the computer, the UPS module should be ON. When the computer starts consuming power, the UPS module will automatically be activated. After starting, the computer will boot the LOADER and primary software into its volatile memory.

Special backup software referred to herein as "BRAM" will then be loaded from the non-volatile storage J into the volatile memory K for execution.

At first, the program will check if the computer system has previously been shutdown due to power interruption. If it has, the program will jump out from the main flow to restore the stored-up content from the permanent media to the volatile memory and create back the previous working environment. After the restoration, the program will flag the data in the permanent media as "non-reusable".

The program will then continue in the main program to communicate with the UPS module. The computer will send a command to the UPS for UPS module initialisation.

The computer will also request the UPS module including the type of battery F to identify itself by sending the ID code to the computer. From this ID code, the computer will retrieve the information of the battery and of the hardware which is required for determining the essential information like battery capacity, battery voltage, UPS module model, etc., for future operation.

Individual batteries from different supplier, albeit rated with the same output voltage and storage capacity, will in fact differ in their discharge

characteristics over a period of time and depending upon the instantaneous output load.

By way of example, Figure 4 shows the discharge characteristic curves of a Yuasa NP8-6 battery. Two units of batteries are connected in series to provide a 12 V DC supply.

Figure 4A shows the general discharge curve over a period of approximately 4 minutes. This curve demonstrates how the battery terminal voltage will drop while carrying a load of approximately 12A DC switching at 50Hz.

The scale of vertical axis is large and details of the ripples are shown in Figures 4B and 4C.

From the curve of Figure 4A, it can be seen that the voltage drop over the first two minutes is fairly linear. Beyond that the voltage drops tremendously, and within one minute, the voltage has already dropped beyond the non-recommend operational level. It is because of this that precise monitoring of the voltage level during the linear period is required.

Figure 1B shows the discharge curve during the first minute. The peaks of the spikes are approximately 0.3 volt while the down kicks are less than 0.15 volt.

Figure 1C represents the discharge curve during the third minute. The peaks of the curve have diminished to 0.2 volt while the down kicks extend to 0.2 volt.

Also, the overall level of the voltage has dropped to about 11.8 volt (average value).

The value of the curve and the ripples can be accurately converted to a digital form with an 8 bit analogue to digital converter IC. The value can then be read by the computer at high frequency, eg 1K sampling per second. From these readings, the condition of the battery terminal voltage in which it is required to activate the backup module prior to the shutdown of battery can be determined accurately.

During UPS operation, the battery terminal voltage will be read, converted to digital by the SACM. The sampled data will be compared with the pre-recorded data mentioned above and software activated timing for shutdown can be precisely determined because actual status of the battery and the remaining power can be determined fairly precisely from this information.

Different batteries will provide different characteristic curves equivalent to those shown in Figure 4, and the characteristics of different batteries are stored in the software and the correct durabilities chosen when the software determines the particular battery installed in the UPS during installation.

If the UPS is unable to initialize because the battery energy level is low or the ID is not fed back to the computer etc., the computer will raise a warning

message to the operator and will let the operator decide if the computer is to be operated without back-up supply.

If UPS initialization completes, the computer is allowed to perform it's normal operation.

The software activation and control module G will continue monitoring the activity of the UPS module for any mains power interruption.

When mains power is interrupted, the UPS module will issue an alarm signal to the software module G.

A battery condition program will be activated. Battery status will be monitored as will be described below using the information retrieved from using the ID code previously described.

The computer will continue to execute it's normal operation, while the module G is monitoring the battery status.

When the battery status reaches a pre-determined level, such that there is only sufficient capacity left for an orderly shut-down as described below, the software module G will halt the computer's normal operation with a higher priority.

The BRAM software will be re-activated and this will arrange to copy all of the contents in the volatile memory, together with the contents stored in the computer microprocessor's registers, into the permanent media J.

When this process is completed, the program will issue a command to the UPS module to shutdown the AC supply generation via the inverter. When UPS shuts down its AC supply, the computer will also be shut down.

The normal flow of the operation is also completed.

Away from the normal shutdown procedure. An operator intervention process is also provided.

The operator intervention is provided for two reasons.

i. the operator may like to shut down the computer during power interruption and prior to the complete exhaustion of the battery energy for energy saving;

ii. the operator can also make use of the features to freeze the operation, ie. perform an automatic shut down with all volatile information stored, if the computer is left unattended, in other words the operator can instruct the software to perform an orderly shut-down at any time even though the AC mains supply has not been interrupted and the UPS and computer will perform an immediate store and shut down.

Communication between the UPS module and the Software Activation & Control Module G (SACM) can be via a standard 25 pin D subminiature plug and socket.

The configuration, and the signals can be as set out below:

Signal Name	Description	Signal flow	Pin No. UPS side	Pin No. SACM side
UPSR	UPS is at ready for full operation.	UPS to SACM	1	1
BEL	Battery Energy Level signal for minium energy detection	UPS to SACM	2	2
BS	Battery Status for detecting battery energy storage at initialisation	UPS to SACM	3	3
GND	Logic Ground for signal		4,5	4,5
UPSI	UPS initialisation command	SACM to UPS	6	6
GENON	Generation ON signal to SACM while A/C main fail	UPS to SACM	7	7
UPSSD	Command from SACM to UPS for UPS Shutdown	SACM to UPS	8	8
COMPON	Computer ON	SACM to UPS	9	9
UPSD	UPS disable, Disable UPS for non-UPS support operation	SACM to UPS	10	10
UPSID	4 bit code for 16 type of battery type & model	UPS to SACM	13,14,15,16	13,14,15,16
CHRON	UPS charger is ON	UPS to SACM	18	18
FGND	safty ground		22,23	22,23

WE CLAIM:

1. An uninterrupted power supply (UPS) for an electronic computer, comprising battery storage means, an inverter for converting energy from the battery storage means to an AC output for supply to the normal AC input of the power supply of the computer, detector means for detecting an interruption in normal AC mains supply and switching to supply the computer from the inverter, means for monitoring the load current drawn by the computer and adjusting the frequency of operation of the inverter to vary the frequency and so its output to meet the demand, and software means within the computer receiving a signal from the detector means upon interruption of the normal AC mains supply for checking on the level of energy remaining in the battery storage means and, when this level reaches a minimum chosen level, inhibiting further normal operation of the computer and executing a shut-down of the computer by storing the contents of the volatile memory of the computer on permanent media followed by switching off the computer and the UPS.

2. A power supply as claimed in Claim 1 in which the frequency of operation of the inventer is varied between 45 and 85 Hz.

3. A power supply as claimed in Claim 1 or Claim 2 in which the minimum chosen level of the battery storage means is a level at which there is only sufficient battery power to execute the said shut-down of the computer and switch off the computer and UPS.

4. A power supply as claimed in any preceding claim in which the means for monitoring the load current and adjusting the frequency of operation of the inventer comprise determining the voltage drop across a resistor in series with the computer load current, using that voltage drop to control the charging and discharging rate of an RC circuit, providing an output frequency signal from the RC circuit, and operating the inventer according to the said output frequency signal.

5. A power supply as claimed in Claim 4 in which the voltage drop across the resistor is coupled via a photo-coupler to the said RC circuit.

6. A power supply as claimed in any preceding claim in which the software means perform a check when the computer is first switched on to determine the type of battery storage means, and then compare the state of the battery storage means when the UPS is actuated with the known discharge characteristics of the battery storage means, so continuously determining the remaining battery power by comparing the instantaneous battery output with the known characteristics.

7. A power supply as claimed in Claim 6 in which the instantaneous output voltage from the battery storage means as it varies with the operation of the inverter is compared with known values of the battery storage means to determine the remaining battery power.

8. A power supply as claimed in Claim 7 in which the spikes and down kicks of of the discharge curve of the battery storage means are monitored and compared with known values of the battery storage means to determine the remaining battery power.

9. An interrupted power supply substantially as herein described with reference to the accompanying drawings.

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